



Use of Mobile Autonomous Systems for Pollution Control of Inland Water Bodies

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Abstract

In recent years, pollution of continental water resources has become an increasingly serious environmental problem. Plastic, construction and household waste are often dumped in them and in adjacent territories, which leads not only to the deterioration of ecosystems, but also to crises such as floods, pollution of groundwater and drinking water, landslides and other risks. This study examines the possibilities for applying autonomous technical means – aerial and floating – for monitoring and control of pollution. They can provide effective monitoring of large areas with minimal resources, which allows for early detection of unregulated landfills and a faster response. Analyses of existing practices and proposals for increasing their effectiveness are presented.

Keywords: Inland Water Bodies; Pollution; Waste; Drones; Autonomous Vehicles; Unregulated Landfills; Water Resources

Introduction

Pollution of water resources is a global problem that is causing growing concern for the future of the planet and future generations [1]. According to various studies, there are already over 180 million tons of plastic waste in the world's oceans, with the amount increasing by between 4.5 and 12.5 million tons each year [2]. Over 750 tons of plastic end up in the seas adjacent to Europe alone every year, and floating "islands" of waste with an area larger than the territory of Bulgaria have formed in the Pacific Ocean [3,4]. If adequate measures are not taken, the situation could become critical in a few decades.

Plastic is not just an aesthetic problem – it endangers marine life, which gets entangled in the waste or ingests microplastics. These particles also reach humans through

the food chain, and the potential health risks are not yet fully understood [5]. Despite recycling efforts, only 5–8% of plastic packaging is reused, with the rest being lost as a resource. However, if collected and recycled, plastic could provide raw materials for the chemical industry for years to come [6].

Materials and Methods

The current study is motivated by the increasing pollution of water areas and adjacent continental areas, as well as frequent reports in the media and social media of unregulated landfills near rivers, dams and canals. The main goal is to limit the accumulation of plastic and other slowly degradable waste in inland water bodies by creating an integrated monitoring system combining autonomous floating and aerial vehicles for more complete coverage of

hard-to-reach areas [7,8].

By analysing the results collected in the study and evaluating various models, a comprehensive pollution monitoring system was developed. It proposes a two-component data collection model that minimizes “white spots” in monitoring.

The first component is an autonomous amphibious vehicle. It will collect visual and sensory information directly from the water surface and the coastline. The intended information collection vehicle will have the following functions:

- Movement on the surface
- Switching to bottom movement at low water levels or small obstacles

It will be able to transmit the following basic data, as appropriate: video recordings, geolocation, environmental parameters. The transmission of information will be carried out in two main ways: local storage in the device’s memory or asynchronous transmission when a mobile connection is available [9].

The second component will be unmanned aerial vehicles (drones). They will monitor large areas from the air and complement ground-based observations. They will have the following features: periodic shooting, georeferencing, repeatable routes.

The data will reach the information processing center as images/video with GPS signatures and there will be the possibility of multispectral or thermal data.

The transmission is planned to be carried out in the form of real-time streaming or packet upload to a center [10].

All information will be collected in a data processing center, with local buffering provided. Due to the frequent lack of internet in remote areas, all devices will record data on built-in memory, which is unloaded after a mission to the data processing center.

The developed prototype envisages that the data will be transferred and stored to a main information center, where centralized in-depth quantitative and qualitative analyses will be performed.

The following analysis tools will be used when processing the data. As software, the initial stage of the project envisages the use of free platforms (e.g. QGIS), followed by the implementation of more powerful solutions as capacity builds.

To achieve more in-depth results from the observation and processing of the collected results, the following methods will be used: mapping, superimposition of time layers, classification of anomalies, assessment of dynamics [11,12].

Due to the specifics of the observations being made, operational restrictions and ethics will be introduced, such as a restriction on observation areas: measurements are only made in publicly accessible areas; official access is requested for pollution data in restricted areas.

The focus of monitoring is on plastics and other non-biodegradable materials [13]. Vegetable waste is not treated as a pollutant and is not included in the scope of the study.

Since the aim of the study is to limit pollution with plastic and other non-biodegradable waste, interaction with government institutions will be of particular importance [14]. The results are shared with the relevant government bodies and departments for follow-up actions, and their follow-up actions are assisted where possible.

When implementing the study, a sequence of activities will be followed, working in the following sequence of implementation:

Planning

Zones: determination of priority areas (riverbeds, shorelines, ravines) where monitoring should be carried out.

Routes: setting trajectories and heights or depths, as well as time windows for the survey. Increased dumping of this type of waste is reported at night and on weekends.

Execution

Synchronization: coordination between vessels and aircraft. Checking for internet connection or mobile network and conducting test runs of amphibians or drones.

Control: management of energy resources and telemetry. Verification of the quality of the transmitted information and its reliability.

Data Collection

Recording: video/photos with GPS markings; sensor values.

Buffer: local storage for reliability

Pre-Treatment

Filtering: noise reduction, distortion correction. A preliminary check of the quality of the transmitted and processed information is necessary.

Georeferencing: merging into single datasets.

Analysis and Reporting

Identification: locating unregulated landfills and risk areas.

Mapping: interactive maps, time series.

Alert: notify response teams.

The following technological integration is observed when implementing the study:

Communications: LTE/5G/ LoRaWAN for flexible transmission; offline mode in case of no coverage.

Positioning: GPS/RTK for centimetre accuracy and mission repeatability.

Onboard Processing: built-in computer modules for preliminary AI analysis and traffic reduction.

Advanced Sensors: thermal, multi/hyperspectral cameras; LIDAR for 3D models near water bodies.

Results and Analysis

Unregulated dumping of plastic and other non-biodegradable waste most often occurs in inaccessible areas – forest areas, riverine areas or abandoned industrial sites. This makes traditional ground patrols expensive and ineffective, as they require significant human and financial resources

[15,16]. Additionally, the illegal nature of the activity makes systematic monitoring difficult. This makes it difficult to detect such dumps and the proposed scheme for conducting monitoring, collecting data and their systematization will have a very good application in detecting unregulated dumps [10].

The use of drones and autonomous vehicles for environmental monitoring offers a number of key advantages [17]:

Rapid coverage of large areas without the need for human presence in dangerous or remote areas.

Precise positioning and mission repeatability through GPS and RTK technologies.

Flexibility in equipping with different sensors according to the specific task.

Lower costs compared to traditional aviation missions (helicopters, airplanes).

Types of Sensors and Applications

To achieve maximum efficiency, amphibians and drones can be equipped with a variety of sensors Table 1.

Sensor Type	Main Function	Example Parameters
Air sensors	Measures CO ₂ , NO _x , PM2.5/PM10, O ₃	Range: 0–5,000 ppm CO ₂ ; accuracy ±2%
Water sensors	Analysis of pH, temperature, toxic substances	pH range 0–14; temperature –10–+70 °C
Radiation detectors	They detect gamma and beta radiation	Sensitivity 0.1 μSv /h
Thermal cameras	Identify thermal anomalies	Resolution 640×512; NETD ≤50 mK
Multi/hyperspectral cameras	Analysis of vegetation, water, soils	5–12 spectral bands (multi); hundreds (hyperspectral)

Table 1: Sensor types.

Integrated technologies are used in monitoring and transmitting information [18], such as:

- GPS/RTK modules – for positioning with an accuracy of 1–2 cm.
- LIDAR systems – for 3D mapping of the relief around water bodies.
- Communications (LTE, 5G, LoRaWAN) – for real-time data transmission.
- Embedded computers (e.g. NVIDIA Jetson) – for data preprocessing “on board”.
- Software platforms (ArcGIS, QGIS, AI modules) – for analysis and visualization of results.
- The work cycle of conducting the experiment can be summarized in the following stages:
- Mission planning – determining zones, routes and altitudes.
- Flight/course execution – sensor synchronization and

energy control.

- Data collection – video recordings, GPS signatures, sensor values.
- Pre-processing – noise filtering, georeferencing, data merging.
- Centralized analysis – anomaly classification, mapping and reporting [19,20].
- Practical examples of the use of such systems are, for example:
- In the municipality of Yambol, drones with thermal cameras are already successfully locating unregulated landfills, with the data being visualized in interactive maps and submitted to response teams [12,16].
- In the municipality of Burgas, pollution of the waters of the Black Sea is observed.
- Internationally, universities and companies are developing autonomous drones with solar power,

integrated 5G and AI algorithms for automatic pollution detection in real time.

Conclusion

The combination of various sensors, precise navigation technologies and powerful analytical software turns drones and autonomous vessels into a versatile tool for environmental monitoring. They not only allow for rapid response but also enable the tracking of trends over time – a key factor for sustainable management of natural resources.

The study shows that unregulated waste disposal in and around inland water bodies is a serious and growing problem that requires new approaches to control and prevention. Traditional monitoring methods are expensive, labour-intensive and often ineffective, especially in hard-to-reach areas.

The implementation of autonomous mobile systems – drones and watercraft – offers a practical and cost-effective solution. They allow:

- Early detection of unregulated landfills and pollution.
- More effective waste management and protection of natural resources.
- Saving time and resources through automated monitoring.
- Ability to track trends and dynamics of pollution over time.

The combination of various sensors, precise navigation technologies and analytical software makes these systems a powerful tool for sustainable environmental management. In the future, integration with satellite data, the development of AI forecasting algorithms and the introduction of legislative frameworks can further increase the effectiveness of monitoring.

The most important conclusion is that technology alone is not enough – **a drastic reduction in the amount of plastic** produced and disposed of is also necessary. Only in this way can real and long-term improvement in the state of water resources be achieved and their protection guaranteed for future generations.

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